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Low world oil prices: A chance to reform fuel subsidies and promote public transport? A case study for South Africa

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ABSTRACT

Since the fall in world oil prices in June 2014, the economic and political settings for fossil fuel subsidy reforms have changed. As in many developing economies, in South Africa oil price subsidies are criticized as an inefficient policy instrument because they hamper economic growth, contradict objectives of climate change mitigation and mainly benefit high income households which can afford to own a car.

Public transportation services are the mobility option for poorer South African households, but are often unavailable and unaffordable due to insufficient governmental subsidization. Thus, the inefficient fuel subsidies and the insufficient subsidies for public transportation have complementary adverse effects on inequity with respect to the welfare of poor households and their mobility.

In this study, a computable general equilibrium model simulates the decrease in world oil prices, the reduction in fuel subsidies and two options for reallocation of these subsidies to support the transport sector: either as consumer price support or as subsidies to production in the passenger transport sector. The simulations indicate improved affordability and availability of public transportation services and clearly show positive impacts for the economy, unemployment and household income. They also give some clues on how to improve the transport system in South Africa to pre-empt the situation when oil prices pick up again.

1. Introduction

After four years of relative stability, world crude oil prices fell sharply between June 2014 and January 2015. The drop was much greater than that of non-oil commodity prices (Baffes et al., 2015; Fantazzini, 2016). The drivers explaining this historically significant price drop include: OPEC's abandoning a production target (November 2014); the unexpectedly high supply from geopolitically conflicted regions (Libya, Iraq, Ukraine); the appreciation of the US dollar; the increased supply from unconventional sources (US shale oil, Canadian oil sands, biofuels) and reduced demand growth due to the low growth of developing and emerging economies. The high level of supply (particularly due to higher than expected shale oil production) and muted global oil demand (due to the low economic growth of developing economies) leads us to expect oil prices to remain below the historical average, between $60 and $80 per barrel in the medium term (World Bank Group, 2016; Baumeister and Kilian, 2016).

The fall in oil prices has changed the context to allow for a reform (i.e. reduction) of the criticized fuel subsidy with a limited impact on the prices paid by consumers. In many developing and developed countries, subsidies to consumption and/or production of

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fossil fuels keep fuel prices artificially low in order to provide basic energy and transport services to low income households and to increase their living standards (Barany and Grigonyte, 2015; OECD, 2015). Fuel subsidies often represent large amounts of public money and exceed 5% of GDP in some developing countries (Baffes et al., 2015; Barany and Grigonyte, 2015; OECD, 2015).

Researchers criticize fossil fuel subsidies as a policy instrument not only because of the high governmental expenditures. Fuel subsidies distort market price signals and are characterized by low efficiency in the use of road space and fossil fuel resources. Fossil fuel subsidies even incentivize wasteful consumption and thus act contrary to environmental and climate change mitigation policies. Furthermore, fuel subsidies often create social inequity between rich and poor. They provide more benefits to the high income households, which can afford to drive a car, than to the low income households. Thus, as an instrument to support low income households, fossil fuel subsidies are not effective and even act contrary to the policy objective of more equity (Arze del Granado and Gillingham, 2012). In many developed and developing countries, public approval, vested interests and institutional capacity hamper reasonable reforms of fossil fuel subsidies to gain benefits for economic, environmental and social equity (Dennis, 2016; Keho, 2016; Rentschler, 2016; Baffes et al., 2015; Barany and Grigonyte, 2015; Benes et al., 2015; Gunningham, 2013; Ellis, 2010).

The reallocation of savings arising from reduced fuel subsidies towards more efficient development programs could create growth and more equity (Baffes et al., 2015; OECD, 2015; Benes et al., 2015; Dartanto, 2013). While criticizing the subsidization of fuels as inequity-increasing and inefficient support of private transport, development programs in public transport services could help to improve mobility in a much more efficient and equal way. South Africa is an interesting case study for three main reasons.

First, although South Africa is among the 15 most energy- and greenhouse gas-intensive economies (Adom, 2015), the government still subsidizes fossil fuel consumption through exemptions from the value added tax (VAT) on petrol (OECD, 2015). According to the International Energy Agency (IEA, 2014), fuel subsidies represent around 0.6% of South African gross domestic product (GDP).

Second, only about one-quarter (26.1%) of South African households have access to a car and benefit from this VAT exemption as a fuel consumption subsidy (Walters, 2013). Therefore, the fuel subsidy supports the mobility of higher income households, which can afford to own a car, thus contributing to the already high degree of inequality in the country.

Third, public transport services are pointed out to be expensive and not reliable in the country (Statistics South Africa, 2014). Use of such services accounts for an aggregated 3.1% of total costs in household budgets (Statistics South Africa, 2012); the budget share is 1% among the richest households but around 7% of the household budget of the poorest households. Besides affordability of prices, the transport system also lacks accessibility and availability (Walters, 2013) and thus is of relatively low efficiency and effectiveness (FFC, 2014). Households point to the availability of buses as the main problem. They are also dissatisfied with the level of crowding on buses (Statistics South Africa, 2014). Thus, reallocation of fuel subsidies to the transport sector makes sense in this country as it could improve affordability and availability of buses for passengers.

Our study evaluates the impacts of a reallocation of fossil fuel subsidies, in a context of reduced world oil prices faced by South Africa as a study case, using a computable general equilibrium (CGE) model. CGE models are comprehensive tools that capture the relationships between economic activities and economic agents with given macroeconomic constraints. They allow us to simulate the fall in world oil prices and two options to reallocate the fuel subsidies.

We analyse the economic impacts of policy options, which simultaneously address the reform of inequity-increasing and inefficient fuel subsidies and the support of insufficiently developed public transportation services. The analysis of the results provides information on the suitability of the policy reforms by answering the following questions:

- Can the simulated policy options improve the public transport sector with respect to the problems of affordability and availability?
- What are the impacts on the key macroeconomic variables (GDP, unemployment, household income and consumption, and CO_2 emissions) and on intersectoral spillover effects?

The rest of the paper is organized as follows. Section 2 describes briefly the situation of fuel subsidies and public transport in South Africa. Section 3 presents an overview of recent studies on oil prices and subsidies reforms in developing countries. Section 4 describes the modelling framework and the scenario assumptions. Section 5 analyses and discusses the results, while Section 6 draws conclusions for policy implications and further research.

2. Fossil fuel subsidies and the public transport sector in South Africa: An overview

2.1. Subsidies on consumer petrol prices in South Africa

Compared with other developing countries such as Malaysia (Solaymani and Kari, 2014) or Nigeria (Siddig et al., 2014), fossil fuel subsidies are not that high in South Africa, at 0.6% of South African GDP (IEA, 2014). However, they still represent a significant expenditure for the South African government and contribute to the already high degree of inequality between rich and poor. In South Africa, subsidies on fuel consumption are in the form of not collecting the VAT on petrol consumption. In the year 2011–2012, these consumer price subsidies totalled 15,914 million ZAR (about 1.5 billion US dollars) and involved fuels (petrol, diesel) and illuminating paraffin (Green Fiscal Policy Network, 2016).

In South Africa, only 26.1% of households have access to a car and these households benefit most from this VAT exemption as a fuel consumption subsidy (Walters, 2013). According to the National Travel Survey (Statistics South Africa, 2014), a personal car is the main (61.6%) mode of commuting only among the 5th income quintile of households. Table 1 presents the modes of commuting by income quintile according to Kerr (2015). For the poor households in lower income quintiles the number one mode of commuting

Table 1
Commuting modes by income quintile.
Source: adapted from (Kerr, 2015)

	Income quintile					Total
	1	2	3	4	5	
Drive	5.6	8.0	18.8	34.7	61.6	25.5
Public transport	26.9	42.7	39.9	28.6	15.6	30.9
Walk and cycle	46.0	24.9	17.0	14.8	7.2	21.8
Others	21.6	22.9	23.6	20.8	15.0	20.7

is public transport or not motorized (40–70%) (Table 1) and thus they do not benefit from the subsidies on petrol prices.

2.2. Consumer petrol prices in South Africa

In South Africa the petrol price is determined by the government. It consists of the basic fuel price, plus customs and transportation costs, taxes, levies and trade margins. While the basic fuel price follows the world market price, the taxes, trade margins and levies are adjusted. Most of the taxes and levies are defined as percentage of the basic fuel price. The whole sale and retail margins are fixed to ensure sufficient income for sellers and retailers and thus retain petrol supply in rural areas with small demand for petrol (Department of Energy – Republic of South Africa, 2016).

2.3. Public transportation services in South Africa

Subsidizing public transport services provides low income and mobility-disadvantaged households with access to jobs, medical care, schools, retail outlets and other essential destinations (Cervero, 2011). In developing and in developed countries, governments subsidize public transport services by between 10% and almost 100% in order to keep the prices for public transport low and affordable (De Borger and Proost, 2015; Cervero, 2011). However, many authors describe the problem of affordability of prices for poor households and the lack of availability in developing countries as due to an underdeveloped and undercapitalized transport sector (e.g., Falavigna and Hernandez, 2016; Dawood and Mokonyama, 2014; Starkey and Hine, 2014; Cervero, 2013; Faiz, 2011; Finn and Mulley, 2011; Sohail et al., 2006; Carruthers et al., 2005; Booth et al., 2000; Kaltheier, 2002). Thus, subsidies for public transport services often fail (partially) in aiming at the objectives of economic benefits, environmental protection and equity.

With the currently implemented instruments the South African government subsidizes the modes of transportation used by middle income households: the private bus operators, the new Bus Rapid Transport systems in larger cities, the provider of intra-city train services (PRASA) and the Gautrain (Kerr, 2015). However, the majority of public transport users (71%) use minibus taxis. Besides benefitting from infrastructure improvements, minibus services receive only 1% of the total direct subsidy to public transportation in the form of a recapitalization program when replacing taxis (Kerr, 2015).

An important economic impact results from the use of modes of transportation for commuting to work. Table 2 presents the transport cost, travel time and effective tax rate of modes of commuting according to Kerr (2015). Kerr (2015) provides an effective 'tax' rate on hourly earnings that combines the monetary travel cost and commuting times. The most popular transport modes are driving, minibus and walking, the latter two of which are used by the majority of the lower income and poor households (up to quintile 4, see Table 1). The effective 'tax' rate is lowest for walking, bicycling and driving, at less than 20% of income (see Table 2). For the non-motorized modes, the low rates result from low transportation costs. The train is comparable to driving in terms of cost but exceeds the 20% due to long travel times. Furthermore, the train is less accessible and is only used by less than 5% of all commuters. Bus and minibus, walking, and driving are the most important modes of commuting. However, these public transport systems clearly have higher combined monetary and time costs, resulting in a 'tax' rate twice that of driving a personal car. Thus, the public transport modes which are the most popular among low income households (see Table 1, Section 2.2) are at the same time the most expensive in terms of combined monetary costs plus commuting time. Price support policies and increased transport capacities could reduce the downsides of high costs and high commuting time for the public transportation used by low income households.

Table 2
Transport cost, travel time and effective tax rate of commuting modes.
Source: Kerr (2015)

	Share, all commuters (%)	Transport cost share of income (%)	Mean travel time (min)	Effective tax rate on income (%)
Walk	16.7	0.0	24.0	7.7
Cycle	1.1	0.0	34.4	11.1
Drive	28.1	8.0	29.6	15.9
Train	2.4	8.0	51.1	22.2
Bus	5.6	16.0	51.8	40.3
Minibus taxi	26.0	15.0	38.8	29.0

Although the South African government puts forward policies and strategies for improving and promoting public transport (Walters, 2014), progress has been relatively slow. One reason for the slow progress is the lack of funding for implementation of public transportation policies (Walters, 2013; FFC, 2014).

3. Studies on oil prices and fuel subsidy reforms

Several recent studies analyse the impacts of oil price subsidy reforms on developing economies: for example, for China (e.g., Jiang and Lin, 2014; Jiang and Tan, 2013; Lin and Li, 2012; Lin and Jiang, 2011); for India (e.g., Anand, 2016); for Indonesia (e.g., Gunningham, 2013); for Malaysia (e.g., Saari et al., 2016; Solaymani et al., 2015; Solaymani and Kari, 2013, 2014) and for Nigeria (e.g., Rentschler, 2016; Soile and Mu, 2015; Siddig et al., 2014).

Some of the research articles analyse fossil fuel subsidy reforms combined with compensation policies to mitigate the negative economic impacts (e.g., Rentschler, 2016; Gunningham, 2013; Jiang and Tan, 2013; Lin and Jiang, 2011). A few studies analyse reallocation options in which the money saved from reduced fossil fuel subsidies is transferred to households (Solaymani et al., 2015; Siddig et al., 2014) or to a specific sector (Siddig et al., 2014).

For South Africa, many research articles evaluate the impacts of oil prices and energy policies (e.g., Kimemia and Annegarn, 2016; Fowowe, 2016; Matthews, 2014; Chitiga et al., 2012; Vanderschuren et al., 2010; Fofana et al., 2009), or of fossil fuel policy reforms (e.g., Chang, 2016; Adom, 2015; Inglesi-Lotz and Pouris, 2012; Van Heerden et al., 2006). However, these studies consider historical high or increased world oil price scenarios; they do not analyse fossil fuel subsidy reforms under recently fallen oil prices. In other words, in each of them, the removal of fossil fuel subsidies is allocated to another sector of the economy, leading to an increase in the petrol price consumers pay. Only a few policy reports describe the situation of recently fallen oil prices as an opportunity to reduce fuel subsidies (e.g., Benes et al., 2015; Whitley and van der Burg, 2015).

Our study complements the recent literature with a model-based policy impact analysis for South Africa. Unlike most of the existing studies, our study (i) considers recently fallen oil prices as an opportunity to implement a fuel policy reform without the negative impacts that removing fuel subsidies can have on consumers and (ii) evaluates reallocation policies, which specifically target the under-developed public transport services sector. Concretely, the analysed policy scenarios assume a decrease in world oil prices, allowing the South African government to lower the amount of subsidies on fossil fuel by reducing the fuel subsidy rate. Such a fuel subsidy reform is consistent with reducing the criticized inequity resulting from fuel subsidies. The government keeps the fuel price paid by consumers constant, and the amount the government collects from the saved fuel subsidy is used for reallocation in two scenarios designed to improve affordability and availability, which are the critical problems identified for South African public transport.

4. Model framework and scenario assumptions

4.1. Model

The model developed in this paper is an extension of the GCE model “Partnership for Economic Policy 1-1” (PEP 1-1) fully described in Decaluwé et al. (2013). Several assumptions have been adjusted for an improved representation of the South African economy. For the list of equations, variables and parameters describing the model, see Appendix A.

Domestic output is presented in a four-level production process. At the first level, for each activity, production is an input-output type function of value added and intermediate consumption. At the second level, we assume that composite labor can be substituted for capital following a constant elasticity of substitution (CES) type of function.

Following our SAM, labor is disaggregated between highly skilled, skilled, semi-skilled and low-skilled. To take this disaggregation into account in our modelling, and given that it is not relevant to substitute a highly skilled worker for an unskilled worker, we assume that at the third level, composite labor is a CES function between composite skilled and composite unskilled labor. At the fourth level, the composite skilled labor demand is a CES function between skilled and highly skilled workers. Composite unskilled labor demand is also described with a CES function between low-skilled and semi-skilled.

The model has four different types of agents. First, households are disaggregated by income quintile. Each type of household receives capital and labor income (given their endowment) and transfers from other institutions. The poorer households (quintile 1) receive transfers from the government while richer households (quintile 5) receive dividends from firms. Households pay direct taxes to the government, and spend their disposable income by consuming and saving.

Firms mainly derive their income from capital income and transfers from other institutions. They pay dividends to the different institutions, direct taxes and save. The government collects direct taxes on households and firms and indirect taxes on activities and commodities (export taxes, tariffs, value added taxes and taxes on production). It makes transfers to other agents, buys commodities and saves. Finally, the rest of the world income comes from its sales on the South African market, income from capital and labor (cross-border workers for instance) and transfers from other institutions (mainly government and firms). It buys commodities (i.e., South Africa’s exports) and makes transfers to households (remittances). The difference between the rest of the world’s spending and income is the current account balance.

South African producers can either sell their products on the domestic market or export them, following a CET (constant elasticity of transformation) type of function. On the demand side, consumers can either buy commodities which are produced domestically or imported. Their choice will be influenced by the relative prices of domestically produced and imported commodities as well as the elasticity of substitution between the imported and the domestic commodity.

We extended the standard PEP1-1 model by computing per sector CO_2 emissions following Solaymani and Kari (2014). The CO_2 emissions are computed using a fossil fuel emissions factor multiplied by the quantity of the demand for fossil fuel in the sector.

In terms of closure rules, we assume that the nominal exchange rate is the numeraire of the model. We assume that South Africa is a small country, and therefore has no influence on world prices. Therefore, world prices for all commodities are fixed. Moreover, we assume that the current account balance is fixed. In other words, South Africa cannot borrow as much as it wants from the rest of the world. In the domestic market, the fuel price paid by consumers is fixed, while the subsidy rate for fuel adjusts.

Labour is mobile across sectors. However, we assume that the full employment hypothesis does not hold in the South African case. Indeed, South Africa faces high unemployment (26.7%), especially for semi-skilled and unskilled labor. The labor market is characterized by an active role of unions involved in negotiating salaries and wages, and working conditions. In terms of modelling, we will assume that we have a minimum wage, and therefore wages are strongly rigid downwards. Finally, capital demand is mobile across activities, representing a long-term situation where the economy has time to adjust.

4.2. Data

Our CGE model is based on the Social Accounting Matrix (SAM) by Davies and Thurlow (2013). The SAM represents a snapshot of the South African economy for the year 2009 in terms of the different flows (transactions and transfers) between productive activities, factors of production and economic agents.[1] The SAM has 50 activities and 80 commodities. There are 2 production factors: capital and labor. Labour is disaggregated between workers with primary education or less (i.e., unskilled), workers with completed middle school (i.e., semi-skilled), workers with completed secondary school (i.e., skilled) and workers with some tertiary education (i.e., highly skilled). There are four different types of institutions: firms, households, government and the rest of the world. Households are disaggregated by income quintile. Finally, there are two investment accounts: savings and changes in stocks. For the purpose of this study, the transport sector was further disaggregated into land transport, air, water and support transport. From the SAM, we find that land transport accounts for roughly three-quarters of total transport sector activity in the country, far ahead of support transport (15%) and water and air transport (10%). For the purpose of our study, we will focus on land transport, as it is the main transport poor households are likely to use. The aggregate commodity for transport in the original SAM was additionally split between passenger transport, freight transport and support transport. Along with the SAM, some additional data such as elasticities are required. Income elasticities are borrowed from Maisonnave et al. (2015) whereas trade elasticities are taken from Gibson (2003).

4.3. Scenario assumptions

The forecast for average world crude oil prices in 2030 is 80.0 $US/barrel, about 83% of the price in 2014 (96.2 $US/barrel) (World Bank Group, 2017). However, instead of a 17% decrease, we consider a caution margin by simulating only the half of this forecasted price decrease, for an 8% decline. We are cautious with the magnitude of the decrease given that: (i) The SAM used is based on the year 2009, in which the South African economy faced low oil prices. Thus, the relative decrease cannot be as large relative to the reference price in 2014. (ii) The assumption of small price increases might avoid overestimation of price and policy impacts. Impacts of more extreme price shocks can be derived from the simulated results. Taking the illustrative results for small price decreases might more easily contribute additional value to the scientific debate than simulation of mid-range and/or exaggerated larger price decreases.[2]

We evaluate the impacts of an 8% decrease in world oil prices on the economy. Differently from other studies, we assume that the government does not pass this decrease on to the consumer price. Instead, the government maintains the oil price paid by consumers and adjusts the fuel subsidy rate. In other words, the decrease in world oil prices is not experienced directly by the consumers, but it creates fiscal space, as total fuel subsidies are lower.[3] The amount the government collects from the subsidy savings is reallocated to subsidize the commodity price of passenger transportation services in Scenario 1. This reallocation represents a policy option which targets improved affordability of public transportation for poor households. In Scenario 2, the total savings from the reduced fuel subsidy is reallocated to the land transport sector to increase transport capacities (e.g., the number of minibuses). This reallocation option aims at improving the availability of public transport and is consistent with the South African government's plans to support the improvement of the transport sector (see FFC, 2014). In both scenarios, the government is taking advantage of the fact that world oil prices have declined in order to reallocate its fuel subsidy without increasing the oil-related prices paid by consumers. Appendix B provides a detailed description on the modelling of the reallocation of fuel subsidies.

5. Results and discussion

The results of the simulated scenarios allow us to draw insights about effects on the South African economy brought about by a sustained reform in petrol subsidies, in a context of reduced world oil prices. Impacts of the simulated reforms are indicated by different macroeconomic variables (Section 5.1), with respect to the different production sectors (Section 5.2), and in terms of effects on the different institutions of the economy (Sections 5.3 and 5.4).

[1] For the construction of this SAM, please refer to Davies and Thurlow (2013).

[2] Results for varied assumptions of oil price decreases are presented in Appendices C1 and C2.

[3] We find that an 8% decrease in world oil prices leads to a 20% decrease in total oil-related subsidies.

Table 3
Impact on some selected variables (% or percentage point change from initial situation).
Source: simulation results

		Scenario 1	Scenario 2
Real GDP	%	0.07	0.22
Total investment	%	0.07	0.49
Unemployment rate (unskilled)	Percentage points	−0.05	−0.2
Unemployment rate (semi-skilled)	Percentage points	−0.11	−0.39
Unemployment rate (skilled)	Percentage points	−0.14	−0.41
Unemployment rate (highly-skilled)	Percentage points	−0.12	−0.4
CO_2 emissions	%	−0.08	−0.28
Consumer price index	%	−0.1	0.06

5.1. Macroeconomic and sectoral effects

Table 3 presents the impact of the simulated policies on selected macroeconomic variables. In Scenario 1 the mechanism of transmission is a demand-driven effect, wherein households spend less income on transportation and consume more transportation services, and also allocate more income to other purchases. The simulated policy in Scenario 2 leads to a reduction in the production price, leading to lower consumer prices for transport and thus additionally inducing increased demand.

Thus, in both scenarios households spend less on transportation services, enabling them to increase their consumption of other commodities produced by other sectors (e.g., agricultural commodities, services). To produce more, firms would hire more workers, leading to reduced unemployment rates for all categories of workers. Similarly, the increase in the labor demand of firms would have a positive impact on wages for the different categories of workers.

In Scenario 2 the effects are generally stronger than in Scenario 1 because the main transmission mechanism comes from “land transport” activities, which create stronger inter-sectoral spillovers. With the subsidy to the land transport sector, firms in this sector would increase their production; they would expand their transport capacities (e.g., get more mini buses, or taxis) hire more workers, and increase their purchases of inputs produced by other industries. In terms of intermediate consumption, land transport is particularly intensive in petrol, trade services, leasing, rental services and other business services. Thus, the increase in production of the land transport sector will increase CO_2 emissions of the sector and have a positive intersectoral impact on other sectors, which will need to hire more workers in order to face this increase in demand.

In both scenarios, GDP rises due to the fact that economic sectors hire more workers in order to produce more. Indeed, in Scenario 1, the decrease in passenger transport prices leads to an increase in the demand of households for this commodity; to meet this increase, transport activities need to produce more, and thus hire more workers. Transport activities will also increase their intermediate consumption and so there will be positive intersectoral effects. In Scenario 2, savings from the reduced subsidy on oil-related commodities is transferred to the transport sector, in order to reduce its production costs. This increases its production, and to produce more the sector will need more workers (i.e. a decrease in unemployment) and more intermediate inputs. The phenomenon is greater in Scenario 2 as the transport sector is directly affected. Respectively, GDP increases by 0.07% in Scenario 1 and 0.22% in Scenario 2.

In Scenario 1, the decrease in the consumer price index combined with the reduced unemployment rate can be easily concluded to result in improved affordability of public transportation services, since households may be able to spend less money on public transport. In Scenario 2 the increase in the production of public transport services improves its availability.

We assume that the fuel price paid by final consumers (households and firms) is held constant. The general decrease in commodity prices, especially in Scenario 1, while holding fuel prices constant, make the fuel prices relatively more expensive. This appears to negatively affect fuel intensive sectors. They reduce their production and consequently their CO_2 emissions. The result of reduced CO_2 emissions is in line with the beneficial impact of reduced fossil fuel usage on total CO_2 emissions described in other studies (e.g., Acar and Yeldan, 2016; Dennis, 2016; Solaymani and Kari, 2014; Kohler, 2013).

Table 4
Production, labor demand and emissions in the land transport sector (% change from the initial situation).
Source: simulation results

		Scenario 1			Scenario 2		
		Land transport	Air and water transport	Support transport	Land transport	Air and water transport	Support transport
Production	Change in%	0.12	3.51	−0.35	6.53	−32.37	0.90
Labour demand	Change in%	0.19	3.59	−0.30	6.88	−32.10	1.17
CO_2 emissions	Change in%	0.12	3.51	−0.35	6.53	−32.37	0.90

5.2. Effects on the land transport sector

Table 4 presents the impact of the simulated policies on production, labor demand and CO_2 emissions. In both simulations, the production of the land transport sector increases. In Scenario 2 the increase in production, labor demand and in CO_2 emissions are larger than in Scenario 1 (see Table 4). These relatively high increases in Scenario 2 indicate that the simulated policy option is an effective measure to improve the production and thus availability of transport services.

The sector hires more workers and increases its production. A side effect of this increase in transport services is increased CO_2 emissions from the sector. However, the model results do not provide information about the reduction in CO_2 emissions due to reduced usage of private cars. Thus, we can only assume that the substitution of private transport by public transport should result in a net decrease in the combined CO_2 emissions of private and public passenger transport.

The other transport sectors are affected by the modeled changes to the passenger transport policy. As mentioned earlier, the transport sector is comprised of three different types of transport: land transport, water and air transport, and support transport. From the SAM, we can see that the former represents 75% of total transport services. The two other sectors represent only a small share of total transport, 15% for support transport and barely 10% for the water and air transport sector. Both the land transport and the water and air sector provide passenger transport and freight transport. In the second scenario, subsidizing land transport leads to a reduction in the land transport price, and therefore we observe a switch from the water and air transport sector to the land transport sector, as the land transport price is relatively cheaper. Note that the initial value for water and air transport is relatively low, explaining the relatively large percentage change.

5.3. Firms' and government's income and total investment

Firms' income rises in both scenarios due to the increase in capital income. Both direct taxes paid to the government and their savings would increase. Government income declines slightly in the first scenario (-0.01%) due to reduced taxes collected on fuel. As we mentioned earlier, the fuel price is relatively higher than all of the other commodities, since it is held constant whereas prices of other commodities decline. The relatively high fuel price reduces fuel demand. In the second scenario, government income rises. As government spending is constant, government savings rise. Given the increase in savings of all agents, total investment increases.

5.4. Impact on households

Table 5 presents the impact of the simulated policies on income and real consumption and Table 6 presents the impact on the consumption of passenger transport services. Households derive their income mainly from labor and capital income and transfers from other agents. In both scenarios, the increased hiring of workers by industry leads to an increase in household income. The increase in household income combined with reduced prices of most commodities leads to an increase in households' real consumption (see Table 5). Furthermore, direct taxes paid to the government and savings both increase as they are a share of households' income. In Scenarios 1 and 2 the increase in income and real consumption indicate that the simulated policy options result in an increase in the welfare of households.

From the above table, we can see that each category of households benefit from the reform in both simulations. Given the increase in their real consumption, households will increase their demand for passenger transport services (see Table 6). The increase is greater in Scenario 1 as the policy option is to subsidize the price of this commodity. The stronger increase in transport services for the poorer households (Q1 to Q3) reflects their higher demand for public transportation services and that the policy option is effective for the targeted poor households.

6. Conclusions and policy implications

The present study analyses the impact of a reallocation of fossil fuel subsidies to subsidies for the public transport sector in South Africa using the opportunity provided by the decrease in world oil prices to finance the reallocation of subsidies without changing the price paid by consumers for oil-related products. Fossil fuel subsidies and subsidies for public transport services both target access to mobility for the poor. Particularly in developing countries, the two policy instruments act against each other in terms of efficiency

Table 5
Change in income and real consumption for different income quintiles of households (% change from the initial situation).
Source: simulation results

	Scenario 1		Scenario 2	
	Income	Real consumption	Income	Real consumption
Q1	0.07	0.17	0.32	0.27
Q2	0.09	0.19	0.37	0.31
Q3	0.10	0.20	0.39	0.33
Q4	0.11	0.21	0.39	0.34
Q5	0.09	0.20	0.37	0.31

Table 6
Consumption of passenger land transport of different income quintiles of households (% change from the initial situation).
Source: simulation results

Quintile	Scenario 1	Scenario 2
Q1	1.28	0.19
Q2	1.30	0.22
Q3	1.28	0.21
Q4	1.20	0.18
Q5	1.04	0.11

and environmental impacts.

In South Africa the benefits of fossil fuel subsidies are more towards rich households. Also, the subsidies granted for public transportation mainly target the mode of transportation used by middle income households (e.g. private bus operators) and thus benefit wealthier households more than the poor (see Section 2.3). Furthermore, subsidies for public transportation are still not sufficient to allow affordability and availability for the poor. Thus, despite aiming at more equal access to mobility for the poor, the downside of the instruments is that they have counterproductive effects which increase inequity.

The present study presents the reallocation of fossil fuel subsidies to the transport sector in South Africa as an effective policy option to improve the affordability and availability of public transportation services for low income households. Simulating the reallocation as price subsidies indicates the improved affordability as shown by increased household consumption of transport services. The increases in income, real consumption, employment and GDP indicate improvements for South African households and the economy. The reallocation of the fuel subsidy to the land transport sector leads to improved availability via increased production in the transportation sector. The positive economic benefits (increased real household income, employment and GDP) result from significant spillover effects between the transport sector and other sectors (e.g., automobile industry, construction).

Further research is required to find the optimal combination of the two reallocation options to promote both affordability and availability, and also to create a maximum of economic benefits. Moreover, a complementary micro analysis could contribute to a deeper analysis on household poverty and inequality. In both scenarios total industrial CO_2 is lower, indicating positive environmental impacts. However, the analysis of environmental aspects needs to be more disaggregated in further research.

Early implementation of the reallocation options presented could allow for the promotion and development of public transportation in order to pre-empt when world oil prices go back up again. Thus, the presented reallocation options could contribute to sustainable economic growth in South Africa.

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Appendix A. List of equations, variables and parameters

1. Equations

1. Production

(1) $VA_j = v_j XST_j$

(2) $CI_j = io_j XST_j$

(3) $VA_j = B_j^{VA}\left[\beta_j^{VA} LDC_j^{-\rho_j^{VA}} + (1-\beta_j^{VA}) KDC_j^{-\rho_j^{VA}}\right]^{-1/\rho_j^{VA}}$

(4) $LDC_j = \left[\frac{\beta_j^{VA}}{1-\beta_j^{VA}} \frac{RC_j}{WC_j}\right]^{\sigma_j^{VA}} KDC_j$

(5) $LDC_j = B_j^{LDC}\left[\beta_j^{LDC} LDU_j^{-\rho_j^{LDC}} + (1-\beta_j^{LDC}) LDS_j^{-\rho_j^{LDC}}\right]^{-1/\rho_j^{LDC}}$

(6) $LDU_j = \left[\frac{\beta_j^{LDC}}{1-\beta_j^{LDC}} \frac{WSK_j}{WUSK_j}\right]^{\sigma_j^{LDC}} LDS_j$

(7) $LDU_j = B_j^{LDU}\left[\sum_{usk} \beta_{usk,j}^{LD} LD_{usk,j}^{-\rho_j^{LDU}}\right]^{-1/\rho_j^{LDU}}$

(8) $LDS_j = B_j^{LDS}\left[\sum_{sk} \beta_{sk,j}^{LD} LD_{sk,j}^{-\rho_j^{LDS}}\right]^{-1/\rho_j^{LDS}}$

(9) $LD_{usk,j} = \left[\frac{\beta_{uskl,j}^{LD} WUSK_j}{WTI_{usk,j}}\right]^{\sigma_j^{LDU}} (B_j^{LDU})^{\sigma_j^{LDU}-1} LDU_j$

(10) $LD_{usk,j} = \left[\frac{\beta^{LD}_{uskl,j} WUSK_j}{WTI_{usk,j}}\right]^{\sigma^{LDU}_j} (B^{LDU}_j)^{\sigma^{LDU}_j - 1} LDU_j$

(11) $LD_{sk,j} = \left[\frac{\beta^{LD}_{skl,j} WSK_j}{WTI_{sk,j}}\right]^{\sigma^{LDS}_j} (B^{LDS}_j)^{\sigma^{LDS}_j - 1} LDS_j$

(12) $KDC_j = B^{KD}_j \left[\sum_k \beta^{KD}_{k,j} KD^{-\rho^{KD}_j}_{k,j}\right]^{-1/\rho^{KD}_j}$

(13) $KD_{k,j} = \left[\frac{\beta^{KD}_{k,j} RC_j}{RTI_{k,j}}\right]^{\sigma^{KD}_j} (B^{KD}_j)^{\sigma^{KD}_j - 1} KDC_j$

(14) $DI_{i,j} = aij_{i,j} CI_j$

2. Income and Savings:

2.1. Households:

(15) $YH_h = YHL_h + YHK_h + YHTR_h$

(16) $YHL_h = \sum_l \lambda^{WL}_{h,l} (W_l \sum_j LD_{l,j})$

(17) $YHK_h = \sum_k \lambda^{RK}_{h,k} (\sum_j R_{k,j} KD_{k,j})$

(18) $YHTR_h = \sum_{ag} TR_{h,ag}$

(19) $YDH_h = YH_h - TDH_h - TR_{gvt,h}$

(20) $CTH_h = YDH_h - SH_h - \sum_{agng} TR_{h,agng}$

(21) $SH_h = PIXCON^{\eta} shO_h - sh1_h YDH_h$

2.2. Firms

(22) $YF_f = YFK_f + YFTR_f$

(23) $YFK_f = \sum_k \lambda^{RK}_{f,k} (\sum_j R_{k,j} KD_{k,j})$

(24) $YFTR_f = \sum_{ag} TR_{f,ag}$

(25) $YDH_h = YF_f - TDF_f$

(26) $SF_f = YDF_f - \sum_{ag} TR_{f,ag}$

2.3.Government

(27) $YG = YGK + TDHT + TDFT + TPRODN + TPRCTS + YGTR$

(28) $YGK = \sum_k \lambda^{RK}_{gvt,k} \left(\sum_j R_{k,j} KD_{k,j}\right)$

(29) $TDHT_t = \sum_h TDH_h$

(30) $TDFT = \sum_f TDF_f$

(31) $TPRODN = TIWT + TIKT + TIPT$

(32) $TIWT = \sum_{l,j} TIW_{l,j}$

(33) $TIKT = \sum_{k,j} TIK_{k,j}$

(34) $TIPT = \sum_j TIP_{l,j}$

(35) $TPRCTS = TICT + TIMT + TIXT + SUBT$

(36) $TICT = \sum_i TIC_i$

(37) $SUBT = \sum_i SUBS_i$

(38) $TIMT = \sum_i TIM_i$

(39) $TIXT = \sum_i TIX_i$

(40) $YGTR = \sum_{agng} TR_{gvt,agng}$

(41) $TDH_h = PIXCON^{\eta} ttdhO_h - ttdh1_h YH_h$

(42) $TDF_f = PIXCON^{\eta} ttdfO_f - ttdf1_f YFK_f$

(43) $TIW_{l,j} = ttiw_{l,j} W_l LD_{l,j}$

(44) $TIK_{k,j} = ttik_{k,j} R_{k,j} KD_{k,j}$

(45) $TIP_j = ttip_j PP_l XS_j$

(46) $TIC_i = ttic_i \left[(PL_i + \sum_{ij} PC_{ij} tmrg_{ij,i}) DD_i + ((1 + ttim_i) PWM_i e + \sum_{ij} PC_{ij} tmrg_{ij}) IM_i\right]$

(47) $SUBS_i = ttsub_i \left[(PL_i + \sum_{ij} PC_{ij} tmrg_{ij,i}) DD_i + ((1 + ttim_i) PWM_i e + \sum_{ij} PC_{ij} tmrg_{ij}) IM_i\right]$

(48) $TIM_i = ttim_i PWM_i e IM_i$

(49) $TIX_i = ttix_i (PE_i + \sum_{ij} PC_{ij} tmrg^X_{ij,i}) EXD_i$

(50) $SG = YG - \sum_{agng} TR_{agng,gvt} - G$

2.4. Rest of the World

(51) $YROW = e \sum_i PWM_i IM_i + \sum_k \lambda^{RK}_{row,k} (\sum_j R_{k,j} KD_{k,j}) + \sum_{agd} TR_{row,agd}$

(52) $SROW = YROW - \sum_i PE^{FOB}_i EXD_i - \sum_{agd} TR_{row,agd}$

(53) $SROW = -CAB$

2.5. Transfers

(54) $TR_{agng,h} = \lambda^{TR}_{agng,h} YDH_h$

(55) $TR_{gvt,h} = PIXCON^{\eta} trO_h - tr1_h YH_h$

(56) $TR_{ag,f} = \lambda^{TR}_{ag,f} YDF_f$

(57) $TR_{agng,'gvt'} = PIXCON^{\eta} TR^{O}_{agng,'gvt'}$

(58) $TR_{agd,'row'} = PIXCON^{\eta} TR^{O}_{agd,'row'}$

3. Demand

(59) $C_{i,h} PC_i = C^{MIN}_{i,h} PC_i + \gamma^{LES}_{i,h} (CTH_h - \sum_{ij} C^{MIN}_{ij,h} PC_{ij})$

(60) $GFCF = IT - \sum_i PC_i VSTK_i$

(61) $PC_i INV_i = \gamma^{INV}_i GFCF$

(62) $PC_i CG_i = \gamma^{GVT}_i G$

(63) $DIT_i = \sum_j DI_{i,j}$

(64) $MRGN_i = \sum_{ij} tmrg_{i,ij} DD_{ij} + \sum_{ij} tmrg_{i,ij} IM_{ij} + \sum_{ij} tmrg^{X}_{i,ij} EXD_{ij}$

4. Producer Supplies of products and International trade

(65) $\mathrm{XST_j} = \mathrm{B^{XT}_j} \left[\sum_{\mathrm{i}} \beta^{\mathrm{XT}}_{\mathrm{j,i}} \mathrm{XS}^{\rho^{\mathrm{XT}}_{\mathrm{j}}}_{\mathrm{j,i}} \right]^{\frac{1}{\rho^{\mathrm{XT}}_{\mathrm{j}}}}$

(66) $XS_{i,j} = \frac{XST_j}{(B^{XT}_j)^{1+\sigma^{XT}_j}} [\frac{P_{j,i}}{\beta^{XT}_j PT_j}]^{\sigma^{XT}_j}$

(67) $XS_{j,i} = B^{X}_{j} [\beta^{X}_{j,i} EX^{\rho^{X}_{j,i}}_{j,i} + (1-\beta^{X}_{j,i}) DS^{-\rho^{X}_{j,i}}_{j,i}]^{-\frac{1}{\rho^{X}_{j,i}}}$

(68) $EX_{j,i} = [\frac{1-\beta^{X}_{j,i}}{\beta^{X}_{j,i}} \frac{PE_i}{PL_i}]^{\sigma^{X}_{j,i}} DS_{j,i}$

(69) $EXD_i = EXD^{O}_i \left(\frac{ePWX_i}{PE^{FOB}_i} \right)^{\sigma^{XD}_i}$

(70) $Q_i = B^{M}_i [\beta^{M}_i IM^{-\rho^{M}_i}_i + (1-\beta^{M}_i) DD^{-\rho^{M}_i}_i]^{-\frac{1}{\rho^{M}_i}}$

(71) $IM_i = \left[\frac{\beta^{M}_i}{1-\beta^{M}_i} \frac{PD_i}{PM_i} \right]^{\sigma^{M}_m} DD_i$

5. Prices

(72) $PP_j = \frac{PVA_j VA_j + PCI_j CI_j}{XST_j}$

(73) $PT_j = (1 + ttip_j) PP_j$

(74) $PCI_j = \frac{\sum_i PC_i DI_{j,i}}{CI_j}$

(75) $PVA_j = \frac{WC_j LDC_j + RC_j KDC_j}{VA_j}$

(76) $WC_j = \frac{WUSK_j LDU_j + WSK_j LDS_j}{LDC_j}$

(77) $WTI_{l,j} = W_l (1 + ttiw_{l,j})$

(78) $RC_j = \frac{\sum_k RTI_{k,j} \cdot KD_{k,j}}{KDC_j}$

(79) $RTI_{k,j} = R_k (1 + ttik_{k,j})$

(80) $R_{k,j} = R_k$

(81) $PT_j = \frac{\sum_i P_{j,i} XS_{j,i}}{XST_j}$

(82) $P_{j,i} = \frac{PE_i EX_{j,i} + PL_i DS_{j,i}}{XS_{j,i}}$

(83) $PE^{FOB}_i = (PE_i + \sum_{ij} PC_{ij} tmrg^{X}_{ij,i})(1 + ttix_i)$

(84) $PD_i = (PL_i + \sum_{ij} PC_{ij,} ttmrg_{ij,i})(1 + ttic_i + ttsub_i)$

(85) $PM_i = (1 + ttic_i + ttsub_i)(1 + ttim_i) ePWM_i + \sum_{ij} PC_{ij} ttmrg_{ij,i}$

(86) $PC_i = \frac{PM_i IM_i + PD_i D_i}{Q_i}$

(87) $PIXGDP = \sqrt{\frac{\sum_j (PVA_j + \frac{TIP_j}{VA_j}) VA^{O}_j \sum_j PVA_j VA_j + TIP_j}{\sum_j (PVA^{O}_j VA^{O}_j + TIP^{O}_j) \sum_j \left(PVA^{O}_j + \frac{TIP^{O}_j}{VA^{O}_j} \right) VA_j}}$

(88) $PIXCON_t = \frac{\sum_i PC_i, \sum_h C^{O}_{i,h}}{\sum_{ij} PC^{O}_{ij} \sum_h C^{O}_{ij,h}}$

(89) $PIXINV = \prod_i \left(\frac{PC_i}{PC^{O}_i} \right)^{\gamma^{INV}_i}$

(90) $PIXGVT = \prod_i \left(\frac{PC_i}{PC^{O}_i} \right)^{\gamma^{GVT}_i}$

6. Equilibrium

(91) $Q_i = \sum_h C_{i,h} + CG_i + INV_i + VSTK_i + DIT_i + MRGN_i$

(92) $\sum_j LD_{l,j} = (1-un_l) LS_l$

(93) $\sum_j KD_{k,j} = KS_k$

(94) $IT = \sum_h SH_h + \sum_f SF_f + SG + SROW$

(95) $\sum_j DS_{i,j} = DD_i$

(96) $\sum_j EX_{j,i} = EXD_i$

7. Gross Domestic Product (GDP)

(97) $GDP^{BP} = \sum_j PVA_j VA_j + TIPT$

(98) $GDP^{MP} = GDP^{BP} + TRCTS$

(99) $GDP^{IB} = \sum_{l,j} W_{l,j} \cdot LD_{l,j} + \sum_{k,j} R_{k,j} KD_{k,j} + TPRODN + TPRCTS$

(100) $GDP^{FD} = \sum_i PC_i [\sum_h C_{i,h} + CG_i + INV_i + VSTK_i] + \sum_i PE_i^{FOB} EXD_i - \sum_i e * PWM_i IM_i$

8. Real (volume) variables

(101) $CTH_h^{REAL} = \frac{CTH_h}{PIXCON}$

(102) $G^{REAL} = \frac{G}{PIXGVT}$

(103) $G^{BP.REAL} = \frac{GDP^{BP}}{PIXGDP}$

(104) $G^{MP.REAL} = \frac{GDP^{MP}}{PIXCON}$

(105) $GFCF^{REAL} = \frac{GFCF}{PIXINV}$

9. Other variables

(106) $CO2E_j = \sum_{fuel} em_{fuel} DI_{fuel,j}$

(107) $W_l > W_l^{MIN}$

(108) $[W_l - W_l^{MIN}] un_l = 0$

(109) $ttsub_{,cpasstrans,} = \frac{[SUBSO_{,cpetr,} - SUBS_{,cpetr,}]}{\{[(PE_{cpasstran,} + \sum_{ij} PC_{ij,} ttmrg_{ij,,cpasstran,}) DD_{,cpasstran,}] + [ePWM_{,cpasstran,} + \sum_{ij} PC_{ij} ttmrg_{ij,i} IM_{,cpasstran,}] + TIM_{,cpasstran,}\}}$

2- Variables and parameters

Volume variables

$C_{i,h}$	Consumption of commodity i by type h household
CG_i	Public consumption of commodity i
CI_i	Total intermediate consumption of industry j
$CMIN_{i,h}$	Minimum consumption of commodity i by type h household
CTH_h^{REAL}	Real consumption expenditure of household h
$CO2E_j$	CO2 emissions of industry j
DD_i	Domestic demand for commodity i produced locally
$DI_{i,j}$	Intermediate consumption of commodity i by industry j
DIT_i	Total Intermediate demand for commodity i
$DS_{j,i}$	Supply of commodity i by sector j to the domestic market
$EX_{i,j}$	Quantity of product i exported by sector j
EXD_i	World demand for exports of product i
G^{REAL}	Real current government expenditures on goods and services
$G^{BP.REAL}$	Real GDP at basic price
$G^{MP.REAL}$	Real GDP at market price
$GFCF^{REAL}$	Real gross fixed capital formation
IM_i	Quantity of product i imported
INV_i	Final demand of commodity i for investment purposes (GFCF)
$KD_{k,i}$	Demand for type k capital by industry j
KDC_j	Industry j demand for composite capital
KS_k	Supply of type k capital
$LD_{l,j}$	Demand for type l labor by industry j
LDC_j	Industry j demand for composite labor
LDU_j	Industry j demand for unskilled labor
LDS_j	Industry j demand for skilled labor
LS_l	Supply of type l labor
$MRGN_i$	Demand for commodity i as a trade or transport margin
Q_i	Quantity demanded of composite commodity i
VA_j	Value added of industry j
$VSTK_i$	Inventory change of commodity i
$XS_{j,i}$	Industry j production of commodity i
XST_j	Total aggregate output of industry j

Price variables	
e	Exchange rate; price of foreign currency in terms of local currency
$P_{i,j}$	Basic price of industry j's production of commodity i
PC_i	Purchaser price of composite commodity i (including all taxes and margins)
PCI_j	Intermediate consumption price index of industry j
PD_i	Price of local product i sold on the domestic market (including all taxes and margins)
PE_i	Price received for exported commodity i (excluding export taxes)
$PEFOB_i$	FOB price of exported commodity i (in local currency)
$PIXCON$	Consumer price index
$PIXGDP$	GDP deflator
$PIXGVT$	Public expenditures price index
$PIXINV$	Investment price index
PL_i	Price of local product i (excluding all taxes on products)
PM_i	Price of imported product i (including all taxes and tariffs)
PP_j	Industry j unit cost, including taxes directly related to the use of capital and labor, but excluding other taxes on production
PT_j	Basic price of industry j's output
PVA_j	Price of industry j value added (including taxes on production directly related to the use of capital and labor)
PWM_i	World price of imported product i (expressed in foreign currency)
PWX_i	World price of exported product i (expressed in foreign currency)
$R_{k,j}$	Rental rate of type k capital in industry j
RC_j	Rental rate of industry j composite capital
RK_k	Rental rate of type k capital (if capital is mobile)
$RTI_{k,j}$	Rental rate paid by industry j for type k capital, including capital taxe
W_l	Wage rate of type l labor
WC_j	Wage rate of industry j composite labor
W_l^{MIN}	Minimum wage rate of type l labor
WSK_j	Wage rate of industry j skilled labor
$WTI_{l,j}$	Wage rate paid by industry j for type l labor, including payroll taxes
$WUSK_j$	Wage rate of industry j unskilled labor
Nominal (value) variables	
CAB	Current account balance
CTH_h	Consumption budget of type h household
G	Current government expenditures on goods and services
GDP^{BP}	GDP at basic prices
GDP^{FD}	GDP at purchasers' prices from the perspective of final demand
GDP^{IB}	GDP at market price (income based)
GDP^{MP}	GDP at market prices
$GFCF$	Gross fixed capital formation
IT	Total investment expenditure
SF_f	Savings of type f businesses
SG	Government saving
SH_h	Saving of type h households
$SROW$	Rest-of-the-world saving
$SUBS_i$	Government revenue from subsidies on product i
$SUBT$	Total government revenue from subsidies
TDF_f	Income taxes of type f businesses
$TDFT$	Total government revenue from business income taxes
TDH_h	Income taxes of type h households
$TDHT$	Total government revenue from household income taxes
TIC_i	Government revenue from indirect taxes on product i
$TICT$	Total government receipts of indirect taxes on commodities
$TIK_{k,j}$	Government revenue from taxes on type k capital used by industry j
$TIKT$	Total government revenue from taxes on capital
TIM_i	Government revenue from import duties on product i
$TIMT$	Total government revenue from import duties

TIP_j	Government revenue from taxes on industry j production (excluding taxes directly related to the use of capital and labor)
$TIPT$	Total Government revenue from production taxes (excluding taxes directly related to the use of capital and labor)
$TIW_{l,j}$	Government revenue from payroll taxes on type l labor in industry j
$TIWT$	Total government revenue from payroll taxes
TIX_i	Government revenue from export taxes on product i
$TIXT$	Total government revenue from export taxes
$TPRCTS$	Total government revenue from taxes on products and imports
$TPRODN$	Total government revenue from other taxes on production
$TR_{ag,agj}$	Transfers from agent agj to agent ag
YDF_f	Disposable income of type f businesses
TDH_h	Disposable income of type h households
YF_f	Total income of type f businesses
YFK_f	Capital income of type f businesses
$YFTR_f$	Transfer income of type f businesses
YG	Total government income
YGK	Government capital income
$YGTR$	Government transfer income
YH_h	Total income of type h households
YHK_h	Capital income of type h households
YHL_h	Labor income of type h households
$YHTR_h$	Transfer income of type h households
$YROW$	Rest-of-the-world income
Rates, intercepts and other variable parameters	
shO_h	Intercept (type h household saving)
$sh1_h$	Slope (type h household savings)
trO_h	Intercept (transfers by type h households to government)
$tr1_h$	Marginal rate of transfers by type h households to government
$ttdfO_f$	Intercept (income taxes of type f businesses)
$ttdf1_f$	Marginal income tax rate of type f businesses
$ttdhO_h$	Intercept (income taxes of type h households)
$ttdh1_h$	Marginal income tax rate of type h households
$ttic_i$	Tax rate on commodity i
$ttik_{k,j}$	Tax rate on type k capital used in industry j
$ttim_i$	Rate of taxes and duties on imports of commodity i
$ttip_j$	Tax rate on the production of industry j
$ttiw_{l,j}$	Tax rate on type l worker compensation industry j
$ttix_i$	Export tax rate on exported commodity i
$ttsub_i$	Subsidy rate on commodity i
un_l	Unemployment rate
Parameters	
$aij_{i,j}$	Input-output coefficient
B_j^{KD}	Scale parameter (CES – composite capital)
B_j^{LDS}	Scale parameter (CES – skilled labor)
B_j^{LDU}	Scale parameter (CES – unskilled labor)
B_j^{LDC}	Scale parameter (CES – composite labor)
B_i^{M}	Scale parameter (CES – composite commodity)
B_j^{VA}	Scale parameter (CES – value added)
$B_{i,j}^{X}$	Scale parameter (CET – exports and local sales)
B_j^{XT}	Scale parameter (CET – Total output)
$\beta_{k,j}^{KD}$	Share parameter (CES – composite capital)
$\beta_{l,j}^{LD}$	Share parameter (CES – composite labor)
β_j^{LDC}	Share parameter (CES –labor)
β_i^{M}	Share parameter (CES – composite commodity)

β_j^{VA}	Share parameter (CES – value added)
$\beta_{j,i}^{X}$	Share parameter (CET – exports and local sales)
$\beta_{j,i}^{XT}$	Share parameter (CET – total output)
η	Price elasticity of indexed transfers and parameters
γ_i^{GVT}	Share of commodity i in total current public expenditures on goods and services
γ_i^{INV}	Share of commodity i in total investment expenditures
$\gamma_{i,h}^{LES}$	Marginal share of commodity I in type h household consumption budget
io_j	Coefficient (Leontief – intermediate consumption)
$\lambda_{ag,k}^{RK}$	Share of type k capital income received by agent ag
$\lambda_{ag,agj}^{TR}$	Share parameter (transfer function)
$\lambda_{h,l}^{WL}$	Share of type l labor income received by type h households
ρ_j^{KD}	Elasticity parameter (CES – composite capital)
ρ_j^{LDC}	Elasticity parameter (CES – composite labor)
ρ_j^{LDU}	Elasticity parameter (CES – unskilled labor)
ρ_j^{LDS}	Elasticity parameter (CES – skilled labor)
ρ_i^{M}	Elasticity parameter (CES – composite commodity)
ρ_j^{VA}	Elasticity transformation (CES – value added)
$\sigma_{i,j}^{X}$	Elasticity transformation (CET – Exports and locale sales)
σ_j^{KDC}	Elasticity (CES composite capital)
σ_j^{LDC}	Elasticity (CES composite labor)
σ_j^{LDS}	Elasticity (CES skilled labor)
σ_j^{LDU}	Elasticity (CES unskilled labor)
σ_i^{M}	Elasticity (composite commodity)
σ_j^{VA}	Elasticity (value added)
σ_j^{XD}	Price elasticity of the world demand for exports of export i
σ_j^{XT}	Elasticity transformation (CET – Total output)
$tmrg_{i,ij}$	Rate of margin i applied to commodity ij
$tmrg_{i,ij}^{X}$	Rate of margin i applied to exported commodity ij
v_j	Coefficient (Leontief – value added)
em_{fuel}	Emission factor

3-Sets

j: Activities

$$j \in \left\{ \begin{array}{l} aagri,afore,afish,acoal,aomin,afood,abtob, \\ atext,awear,aleat,afoot,awood,apapr, \\ aprnt,apetr,abchm,aochm,arubb,aplas, \\ aglas,anmet,aironfer,ametp,agmch,aemch, \\ artel,amequ,avehe,aotrn,afurn,aoman, \\ aelec,awatr,acons,atrad,ahotl,alandtrans, \\ awatairtrans,asuptrans,acomm,afsrv,ainsu,areal,ardev, \\ arent,abusi,agovn,aeduc,aheal,aosrv \end{array} \right\}$$

i: Commodities

$$i \in \left\{ \begin{array}{l} cagri,cfore,cfish,ccoal,comin,cmeat, \\ cpfsh,cfveg,coils,cdair,cmill,cstar,cfeed, \\ cbake,csugr,cconf,cpast,cfood,cbtob,cfabr, \\ cmade,ccarp,ctext,cknit,cwear,cleat, \\ cfoot,cwood,cpapr,cprnt,cpetr,cbchm,cfert,cpain, \\ cphar,csoap,cochm,ctyre,crubb,cplas,cglas,ccere,cceme, \\ cnmet,cironfer,cmetp,cengn,cpump,cbear,clift,cmach, \\ crtel,cmequ,cvehe,crail,cotra,cfurn,cjewe,coman, \\ crcyc,celec,cwatr,ccons,ctrad,chotl,cpasstrans,cfreighttrans, \\ csuptrans,ccomm,cfsrv,cinsu,creal,ceduc,cheal,cosrv, \\ crdev,clegl,crent,cbusi,cgovn, \end{array} \right\}$$

$fuel \in i\{ccoal,cpetr\}$

Production factors:

L: *Laborcategories*
$l\varepsilon\{flab-p,flab-m,flab-s,flab-t\}$
K: *capitalcategories*
$k\varepsilon\{fcap\}$

Agents:

$AG \in \{ent,hhq1,hhq2,hhq3,hhq4,hhq5,gov,row\}$

Appendix B. Modelling of the reallocation of fuels subsidies

The amount of total subsidies in the whole economy remains constant; it is the allocation that is different. The receipts from subsidies $SUBS_{\text{'cpetr'}}$ on commodity 'cpetr' is computed as a subsidy rate that is applied on local sales on fuel ($DD_{\text{'cpetr'}}$) and on imports $IM_{\text{'cpetr'}}$. The world price of imports $PWM_{\text{'cpetr'}}$ for petrol is decreasing by 8% in both simulations.

$$SUBS_i = ttsub_i[(PL_i + \sum_{ij} PC_{ij} tmrg_{ij,i})DD_i + ((1 + ttim_i)PWM_i e + \sum_{ij} PC_{ij} tmrg_{ij})IM_i] \tag{1}$$

Ceteris paribus, an 8% lower world oil price will reduce the receipt on subsidies $SUBS_{\text{'cpetr'}}$ collected. The difference between the initial value of petrol subsidies and the total petrol subsidy after the shock is allocated as a subsidy to the passenger transport sector. Eq. (2) below computes the subsidy rate for passenger transport.

$$ttsub_{\text{'cpasstrans'}} = \frac{[SUBSO_{\text{'cpetr'}} - SUBS_{\text{'cpetr'}}]}{\{[(PL_{\text{'cpasstran'}} + \sum_{ij} PC_{ij,} ttmrg_{ij,\text{'cpasstran'}})DD_{\text{'cpasstran'}}] + [ePWM_{\text{'cpasstran'}} + \sum_{ij} PC_{ij} ttmrg_{ij,i} IM_{\text{'cpasstran'}}] + TIM_{\text{'cpasstran'}}\}} \tag{2}$$

This subsidy rate is applied to the consumer price ($PC_{\text{'cpasstran'}}$) that is a weighted average (Eq. (3) below) of the local price PD_i (Eq. (4)) including margins $\sum_{ij} PC_{ij,} ttmrg_{ij,i}$, taxes $ttic_i$ and subsidies $ttsub_i$, and the imported price on national currency PM_i (Eq. (5)) that is computed from the world price PWM_i converted into the domestic currency plus import taxes, commodity taxes, subsidies and margins.

$$PC_i = \frac{PM_i IM_i + PD_i D_i}{Q_i} \tag{3}$$

$$PD_i = (PL_i + \sum_{ij} PC_{ij,} ttmrg_{ij,i})(1 + ttic_i + ttsub_i) \tag{4}$$

$$PM_i = (1 + ttic_i + ttsub_i)(1 + ttim_i)ePWM_i + \sum_{ij} PC_{ij} ttmrg_{ij,i} \tag{5}$$

Therefore, the lower world oil price reduces the subsidies the government pays on this commodity. Instead of reducing the consumer price of oil, the government reallocates the subsidies that are saved due to the lower world oil price and which are transferred either to the price of passenger transport (Scenario 1) or to the land transport sector (Scenario 2).

Appendix C1. Sensitivity analysis for variation in world oil price changes - Scenario 1

Decrease in world oil price by		2%	4%	6%	8%	10%	12%	14%
Real GDP	%	0.02	0.03	0.05	0.07	0.08	0.1	0.12
Total investment	%	0.02	0.03	0.05	0.07	0.09	0.11	0.13
Unemployment rate (unskilled)	pp	−0.01	−0.03	−0.04	−0.05	−0.07	−0.08	−0.1
Unemployment rate (semi-skilled)	pp	−0.03	−0.05	−0.08	−0.11	−0.14	−0.17	−0.2
Unemployment rate (skilled)	pp	−0.03	−0.07	−0.1	−0.14	−0.18	−0.22	−0.26
Unemployment rate (highly-skilled)	pp	−0.03	−0.06	−0.09	−0.12	−0.15	−0.18	−0.21
CO_2 emissions	%	−0.02	−0.04	−0.06	−0.08	−0.1	−0.12	−0.14
Consumer price index	pp	−0.02	−0.05	−0.08	−0.1	−0.13	−0.15	−0.18
Change in production of land transport	%	0.03	0.06	0.09	0.12	0.15	0.18	0.21
Change in production of water and air-transport	%	0.84	1.7	2.59	3.51	4.46	5.44	6.45
Change in production of support transport	%	−0.08	−0.17	−0.26	−0.35	−0.44	−0.54	−0.64
Share of production of land transport (reference)	%	74.15	74.15	74.15	74.15	74.15	74.15	74.15
Share of production of water and air-transport (reference)	%	10.38	10.38	10.38	10.38	10.38	10.38	10.38
Share of production of support transport (reference)	%	15.47	15.47	15.47	15.47	15.47	15.47	15.47
Share of production of land transport (simulation)	%	74.17	74.19	74.21	74.24	74.26	74.28	74.3
Share of production of water and air-transport (simulation)	%	10.46	10.55	10.65	10.74	10.84	10.94	11.05
Share of production of support transport (simulation)	%	15.46	15.45	15.43	15.42	15.41	15.39	15.38
Changes in production shares of land transport	pp	0.02	0.04	0.06	0.09	0.11	0.13	0.15
Changes in production shares of water- and air-transport	pp	0.09	0.18	0.27	0.36	0.46	0.56	0.67
Changes in production shares of support transport	pp	−0.01	−0.03	−0.04	−0.05	−0.07	−0.08	−0.1
Labour demand by land transport	%	0.04	0.09	0.14	0.19	0.24	0.29	0.34
Labour demand by water and air-transport	%	0.86	1.74	2.65	3.59	4.57	5.57	6.61
Labour demand by support transport	%	−0.07	−0.15	−0.22	−0.3	−0.38	−0.46	−0.54
CO_2 emissions from land transport	%	0.03	0.06	0.09	0.12	0.15	0.18	0.21
CO_2 emissions from water and air-transport	%	0.84	1.7	2.59	3.51	4.46	5.44	6.45
CO_2 emissions from support transport	%	−0.08	−0.17	−0.26	−0.35	−0.44	−0.54	−0.64
Income-Q1	%	0.02	0.03	0.05	0.07	0.09	0.11	0.13
Income-Q2	%	0.02	0.04	0.07	0.09	0.12	0.14	0.17
Income-Q3	%	0.02	0.05	0.08	0.1	0.13	0.16	0.19
Income-Q4	%	0.03	0.05	0.08	0.11	0.14	0.17	0.2
Income-Q5	%	0.02	0.05	0.07	0.09	0.12	0.15	0.17
Real Consumption-Q1	%	0.04	0.08	0.13	0.17	0.22	0.27	0.32
Real Consumption-Q2	%	0.05	0.09	0.14	0.19	0.25	0.3	0.35
Real Consumption-Q3	%	0.05	0.1	0.15	0.2	0.26	0.31	0.37
Real Consumption-Q4	%	0.05	0.1	0.15	0.21	0.26	0.32	0.38
Real Consumption-Q5	%	0.05	0.1	0.15	0.2	0.25	0.3	0.36
Consumption of passenger transport Q1	%	0.31	0.62	0.94	1.28	1.62	1.98	2.35
Consumption of passenger transport Q2	%	0.31	0.63	0.96	1.3	1.64	2.01	2.38
Consumption of passenger transport Q3	%	0.31	0.62	0.94	1.28	1.62	1.98	2.35
Consumption of passenger transport Q4	%	0.29	0.58	0.89	1.2	1.52	1.86	2.2
Consumption of passenger transport Q5	%	0.25	0.51	0.77	1.04	1.32	1.61	1.91

Appendix C2. Sensitivity analysis for variation in world oil price changes - Scenario 2

Decrease in world oil price by		2%	4%	6%	8%	10%	12%	14%
Real GDP	%	0.05	0.11	0.16	0.22	0.27	0.33	0.25
Total investment	%	0.12	0.25	0.37	0.49	0.61	0.73	0.67
Unemployment rate (unskilled)	pp	−0.05	−0.1	−0.15	−0.2	−0.25	−0.3	−0.4
Unemployment rate (semi-skilled)	pp	−0.1	−0.2	−0.29	−0.39	−0.49	−0.59	−0.5
Unemployment rate (skilled)	pp	−0.1	−0.21	−0.31	−0.41	−0.52	−0.62	−0.46
Unemployment rate (highly-skilled)	pp	−0.1	−0.2	−0.3	−0.4	−0.5	−0.59	−0.38
CO_2 emissions	%	−0.07	−0.14	−0.21	−0.28	−0.34	−0.41	0.17
Consumer price index	pp	0.01	0.03	0.04	0.06	0.07	0.08	0.06
Change in production of land transport	%	1.71	3.36	4.96	6.53	8.06	9.56	2.33
Change in production of water and air-transport	%	−8.59	−16.81	−24.72	−32.37	−39.78	−46.99	−1.67

Change in production of support transport	%	0.25	0.48	0.7	0.9	1.1	1.29	0.03
Share of production of land transport (reference)	%	74.15	74.15	74.15	74.15	74.15	74.15	74.15
Share of production of water and air – transport (reference)	%	10.38	10.38	10.38	10.38	10.38	10.38	10.38
Share of production of support transport (reference)	%	15.47	15.47	15.47	15.47	15.47	15.47	15.47
Share of production of land transport (simulation)	%	75.42	76.64	77.83	78.99	80.12	81.24	75.88
Share of production of water and air-transport (simulation)	%	9.49	8.63	7.81	7.02	6.25	5.5	10.2
Share of production of support transport (simulation)	%	15.51	15.55	15.58	15.61	15.64	15.67	15.48
Changes in production shares of land transport	pp	1.27	2.49	3.68	4.84	5.98	7.09	1.73
Changes in production shares of water- and air-transport	pp	−0.89	−1.74	−2.57	−3.36	−4.13	−4.88	−0.17
Changes in production shares of support transport	pp	0.04	0.07	0.11	0.14	0.17	0.2	0
Labour demand by land transport	%	1.79	3.53	5.23	6.88	8.51	10.11	7.59
Labour demand by water and air-transport	%	−8.5	−16.65	−24.5	−32.1	−39.48	−46.68	−8.4
Labour demand by support transport	%	0.31	0.61	0.89	1.17	1.43	1.69	0.05
CO_2 emissions from land transport	%	1.71	3.36	4.96	6.53	8.06	9.56	2.33
CO_2 emissions from water and air-transport	%	−8.59	−16.81	−24.72	−32.37	−39.78	−46.99	−1.67
CO_2 emissions from support transport	%	0.25	0.48	0.7	0.9	1.1	1.29	0.03
Income-Q1	%	0.08	0.16	0.24	0.32	0.4	0.49	0.48
Income-Q2	%	0.09	0.18	0.28	0.37	0.46	0.55	0.52
Income-Q3	%	0.1	0.19	0.29	0.39	0.48	0.58	0.52
Income-Q4	%	0.1	0.2	0.3	0.39	0.49	0.59	0.51
Income-Q5	%	0.09	0.19	0.28	0.37	0.46	0.55	0.45
Real Consumption-Q1	%	0.07	0.13	0.2	0.27	0.33	0.4	0.42
Real Consumption-Q2	%	0.08	0.15	0.23	0.31	0.39	0.47	0.46
Real Consumption-Q3	%	0.08	0.16	0.25	0.33	0.41	0.5	0.46
Real Consumption-Q4	%	0.08	0.17	0.25	0.34	0.42	0.51	0.45
Real Consumption-Q5	%	0.08	0.16	0.23	0.31	0.39	0.47	0.39
Consumption of passenger transport Q1	%	0.05	0.11	0.16	0.22	0.27	0.33	0.25
Consumption of passenger transport Q2	%	0.12	0.25	0.37	0.49	0.61	0.73	0.67
Consumption of passenger transport Q3	%	−0.05	−0.1	−0.15	−0.2	−0.25	−0.3	−0.4
Consumption of passenger transport Q4	%	−0.1	−0.2	−0.29	−0.39	−0.49	−0.59	−0.5
Consumption of passenger transport Q5	%	−0.1	−0.21	−0.31	−0.41	−0.52	−0.62	−0.46

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